



U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: UNUSABLE FUEL TEST PROCEDURES
FOR SMALL AIRPLANES

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Initiated by: ACE-100

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Change:

1. PURPOSE. This advisory circular (AC) sets forth an acceptable means, but not the only means, of showing compliance with Federal Aviation Regulation (FAR), section 23.959, Unusable Fuel Supply, during certification flight tests of small propeller driven or turbojet airplanes. Due consideration will be given to any other means of determining compliance the applicant elects to present. This material is neither mandatory nor regulatory in nature and does not constitute a regulation.

2. RELATED FAR SECTIONS AFFECTED.

- a. Section 23.959.
- b. Section 23.1337(b)(1).

3. BACKGROUND.

a. Section 23.959, amendment 23-7, effective September 14, 1969, deleted the specific flight conditions to be tested during determination of unusable fuel. It was found that the specific flight conditions noted in the original section 23.959 did not include certain adverse conditions likely to occur in service. Section 23.959 currently reads as follows:

The unusable fuel supply for each tank must be established as not less than that quantity at which the first evidence of malfunctioning occurs under the most adverse fuel feed condition occurring under each intended operation and flight maneuver involving that tank. Fuel system component failures need not be considered.

b. Further, when the unusable fuel quantity is determined, each fuel quantity indicator should be marked per section 23.1337(b)(1) which currently reads as follows:

Each fuel quantity indicator must be calibrated to read "zero" during level flight when the quantity of fuel remaining in the tank is equal to the unusable fuel supply determined under section 23.959.

c. Based on service experience, certain flight conditions have been found to be critical for small airplanes. Therefore, to provide uniform application of unusable fuel test procedures, some test procedures are considered warranted.

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d. Service experience indicates that taxi turns and turning takeoff with minimum fuel in the tank has resulted in engine stoppage due to fuel starvation during takeoff operation. For this reason, additional tests are considered necessary to assure proper fuel flow during turning-type takeoff with minimum fuel.

4. DEFINITIONS. As used herein, the following definitions and abbreviations apply:

a. Unusable fuel (System) - The total quantity of fuel remaining in the fuel system when the first evidence of engine malfunction occurs under the most adverse fuel feed conditions occurring under each intended operation and flight maneuver involving each fuel tank.

b. V_{FE} - is the maximum airplane flap extended speed.

c. V_{SO} - is the airplane stalling speed or the minimum steady flight speed in the landing configuration.

c. V_X - is the airplane speed for best angle of climb.

e. V_Y - is the airplane speed for best rate of climb.

f. V_{YSE} - is the airplane speed for best rate of climb with critical engine inoperative.

5. ACCEPTABLE MEANS OF COMPLIANCE. The following conditions should be considered during unusable fuel tests:

a. The flight maneuvers for determining unusable fuel discussed in appendix 1 are some conditions considered likely to occur in service and result in the most adverse fuel feed condition.

b. A tank that is not needed to feed the engine under all flight conditions should be tested only for the flight regime for which it was designed (i.e., cruise conditions). Tests for this kind of tank should include slips and skids to simulate turbulence. Suitable instructions on the conditions under which the tank may be used should be provided in a placard or in the Airplane Flight Manual.

c. The term "most adverse fuel condition" is not intended to include radical or extreme maneuvers not likely to be encountered in operation. Judgment should be used in determining what maneuvers are appropriate to the type of airplane being tested.

d. Analyze the fuel system and tank geometry to determine the critical maneuvers for the specific tanks being considered; i.e., main, auxiliary, or cruise tanks and conduct only those tests considered applicable to the airplane being tested. Particular attention should be directed toward the tank or cell geometry and orientation with respect to the longitudinal axis of the airplane and location of supply ports. Care should be taken in planning how the critical attitude

maneuvers are tested so that the test procedure does not result in unconservative, unusable fuel. For instance, if the fuel system analysis showed that a glide at V_{FE} was the critical maneuver, and the test pilot elected to conduct the test by alternatively climbing and gliding for 1,000 feet until the engine malfunctioned, it might be possible to keep refilling the fuel lines during the climbs to sustain engine operation in the glides at lower power setting far beyond the point of engine malfunction that may have been encountered if the tests were done in a prolonged glide. On the other hand, the test maneuvers should be selected using good judgment with regard to the kind of maneuvers the airplane under test will be subjected to in operation. Ground tests using equipment which accurately simulate the airplane fuel system and inflight inertial effects may be considered acceptable.

e. In lieu of determining the actual unusable fuel quantity, the applicant may establish a conservative unusable fuel quantity and conduct necessary tests to show engine malfunction will not occur. If the applicant selects a conservative unusable fuel quantity, all the tests specified in appendix 1 are considered appropriate; however, the method of conducting the test may vary from that used to determine the actual fuel quantity.


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APPENDIX 1. UNUSABLE FUEL TESTS - SECTION 23.959

1. PROCEDURES. The quantity of fuel to be used for the tests should be chosen by the applicant. The selected quantity should be sufficient for determination of unusable fuel by allowing the maneuvers described herein to be performed. The maneuvers are repeated until first evidence of engine malfunction. Repeated maneuvers may result in fuel refilling some bays or tanks; therefore, minimum fuel should be used. For the tests, a malfunction will be considered when engine roughness, partial or total loss of power, fuel pressure loss below minimum, or fuel flow fluctuations are experienced. To assure the most conservative unusable fuel supply value for each tank, another fuel tank should be selected at the first indication of fuel interruption. The fuel remaining in the test tank at the time of malfunction should be drained, measured, and recorded as unusable fuel. If header tanks (small tanks that accumulate fuel from one or more fuel tanks and supply the engine directly) are utilized, the fuel remaining in the header tank should be added to the unusable fuel but would not be shown on the fuel gauge marking. All tests should be conducted at a minimum practical weight or weight determined to be critical for the airplane being tested. The flight testing of a single engine airplane with a one-tank system requires a separate temporary fuel system to supply the engine after fuel starvation occurs.

2. UNUSABLE FUEL DETERMINATION.a. Level Flight at Maximum Recommended Cruise.

(i) Condition a. Maintain straight coordinated flight or bank angles not exceeding 5° until a malfunction occurs.

(ii) Condition b. Simulated turbulent air with +/- half-ball width oscillations at approximately the natural yawing frequency of the airplane until a malfunction occurs.

(iii) Condition c. Skidding turns with 1-ball skid. Hold for 30 seconds and then return to coordinated flight for 1 minute. Repeat until malfunction occurs. Direction of skidding turn should be in the direction most critical with respect to fuel feed.

b. Maximum Climb Power (MCP) Climb at V_x .

(i) Condition a. Straight coordinated flight or bank angle should not exceed 5° until a malfunction occurs.

(ii) Condition b. Simulated turbulent air with +/- half-ball width oscillations at approximately the natural yawing frequency of the airplane until a malfunction occurs.

(iii) Condition c. Skidding turns with 1-ball width skid or full rudder if 1-ball width cannot be obtained. Hold for 30 seconds and then return to coordinated flight for 1 minute. Repeat until a malfunction occurs. Direction of skidding turn should be in the direction most critical with respect to fuel feed.

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c. Maximum Climb Power (MCP) One Engine Inoperative Climb at V_Y . On a multiengine airplane with the critical engine operating, but set at zero thrust to simulate a critical engine out, conduct a straight climb at V_{YSE} utilizing the bank angle and ball displacement used in determining single engine performance. Continue climb until a malfunction occurs.

d. Descent and Approach.

(i) Condition a. Emergency Descent or Rapid Descent. Make a continuous power-off straight descent at V_{FE} with gear and flaps down or follow emergency descent procedures contained in the Airplane Flight Manual (AFM). Continue the test until the first indication of interrupted fuel flow is observed.

(ii) Condition b. Glide at $1.3 V_{SO}$ and Transition to V_Y . Make a continuous power-off glide at $1.3 V_{SO}$ until first indication of interrupted fuel flow is observed. Simulate turbulent air or smooth air condition, whichever is most critical. Verify that with the unusable fuel quantity established with critical tests no interruption of fuel flow will occur when simultaneously making a rapid application of MCP and a transition to V_Y from a power-off glide at $1.3 V_{SO}$.

(iii) Condition c. Slideslip on Approach. Establish a power-off $1.3 V_{SO}$ descent in a landing configuration. Maintain a $1\frac{1}{2}$ ball sideslip in direction found to be critical for fuel system design with sufficient aileron to maintain constant heading (or utilize the maximum sideslip anticipated for the type of airplane). The test should be conducted by slipping for 30 seconds. Continue the test until the first indication of interrupted fuel flow is observed. Verify that with the unusable fuel quantity established with critical tests no interruption of fuel flow will occur when slipping for 30 seconds, followed by a maximum power straight ahead balked landing climb for 1 minute.

3. TESTS TO BE CONDUCTED AFTER UNUSABLE FUEL IS DETERMINED.

a. Taxi Turns and Turning Takeoffs. These maneuvers should be conducted with a quantity of fuel selected by the applicant but should not exceed the flight unusable fuel supply plus 30 minutes fuel supply at MCP. Direction of turns should be most adverse for tank being used. The airplane should be loaded to the approximate minimum flying weight or weight found to be critical for airplane being tested. The engine may not malfunction during each of the following maneuvers found critical for the airplane fuel system:

(i) Make a 90° turn rolling takeoff with the turn rate governed to produce maximum lateral "G" to the point where lateral skidding is evident. Immediately follow the takeoff with a 3-minute climb at V_Y for single-engine airplanes or speed determined under section 23.51 for multiengine airplanes; however, normal flight procedures or operating conditions necessary for safe operations such as proper engine cooling, should be observed.

(ii) Make a 360° clearing turn at a rate appropriate to the airplane, immediately followed by a takeoff and a 3-minute straight climb at V_Y for single-engine airplanes or speed determined under section 23.51 for multiengine airplanes; however, normal flight procedures or operating conditions necessary for safe operations, such as proper engine cooling, should be observed.

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Appendix 1

(iii) Make a 180° turn at normal taxi speed immediately followed by a takeoff and a 3-minute straight climb at V_x for single-engine airplanes or speed determined under section 23.51 for multiengine airplanes; however, normal flight procedures or operating conditions necessary for safe operation, such as proper engine cooling, should be observed.

b. If the fuel quantity to satisfy the above tests is in excess of the 30-minute fuel supply at MCP, the fuel quantity gauge should be marked with a yellow arc (appropriately placarded) from the unusable fuel ("zero" level) to a level corresponding to the amount of fuel used in the above tests. In addition, a flight manual limitation should restrict takeoff with the fuel quantity less than the top of yellow arc.

